SPECTRAL EMISSIVITIES OF BRIGHT AND OXIDIZED METALS AT HIGH TEMPERATURES[1]

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ABSTRACT
Spectral emissivities of bright and oxidized metals at high temperatures were measured. The emissivity measurements are carried out by comparing the radiation heat fluxes of a sample and a black body emitted at a certain temperature. Heat pipes and tubular furnaces are used as sources of black body radiation. The samples were resistively self-heated in a water-cooled bell furnace with vacuum and protective gas equipment. The measuring ranges are 0.6 µm to 16 µm for wavelength and 200 °C up to 1200 °C for temperature. The determined temperature dependencies of the spectral emissivities of bright metals are mostly relative small. Oxide layers lead to strong and, sometimes, temperature dependent changes of spectral emissivities. The accuracy of the measurements was determined as about +/- 3,5 %.

KEY WORDS: bright metals, emissivity; high temperatures; non-ferrous metals; oxide layers, steels.

1. INTRODUCTION

The significance of radiation properties, especially emissivity, as process data for heat technical facilities has increased. Emissivities are required for heat transfer calculations, temperature measurements and process controlling for simple furnaces as well as for continuous running heat facilities and annealing plants with protective atmospheres. The knowledge of these radiation properties is furthermore necessary for the intensification of heat transfer and for energy savings in high temperature plants.

2. MEASURING DEVICE

At University Duisburg-Essen spectral emissivity measurements of solid materials are carried out [1] in a wavelength range from 0.6 to 16 µm, by comparing the radiation heat fluxes of a sample and a black body emitted at a certain temperature, wavelength, direction, and optical angle (see fig. 1). Heat pipes and tubular furnaces are used as sources of black body radiation. A prism monochromator is used for dispersion of radiation. The modulated signal (frequency-stabilized chopper) is measured with three different detectors and a Lock-in-Amplifier.

The spectral emissivity was chosen as target of the measurements, because it gives most and best information about the kind of wavelength dependent radiation at high temperatures. Furthermore, these values can be used for calculations of temperature dependent total and band emissivities.

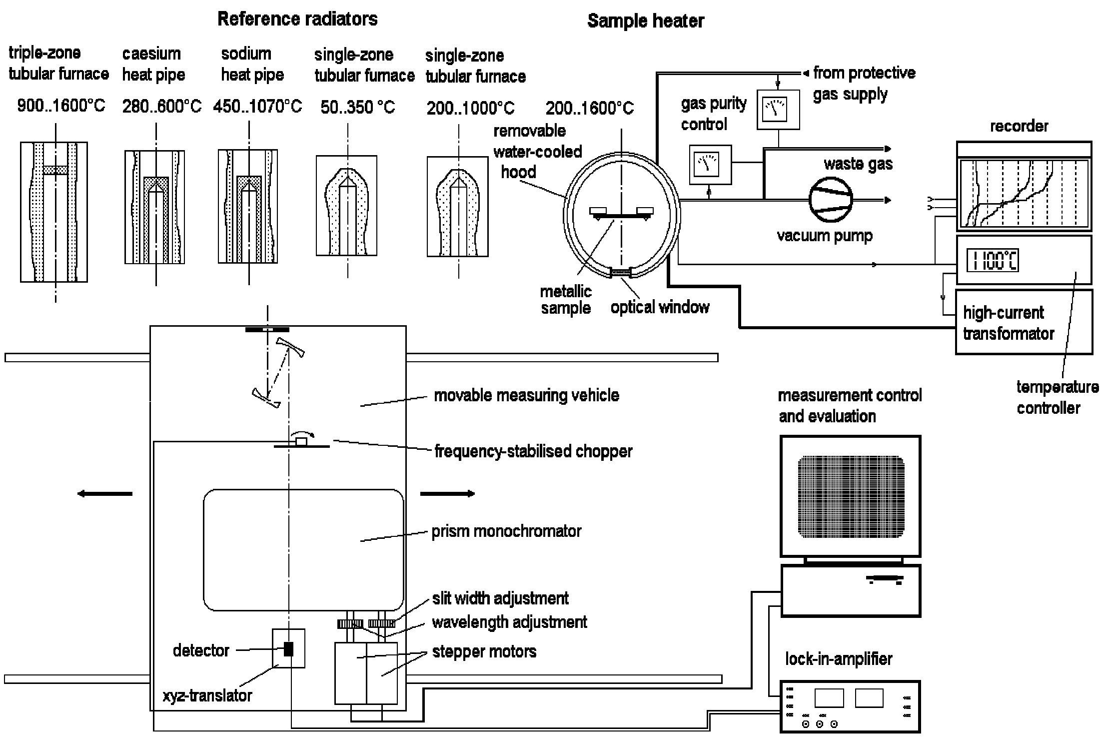

Fig. 1. Scheme of the measurement device.

The emissivity measurements of metals are done by means of a special water-cooled bell furnace. For resistive self-heating of the samples a high-current transformer was used. The inner surface of the bell has a high black coating [2], for optical windows

KBr, and KRS 5 were used. Temperature controllers keep bell and sensors at background (room) temperature. This furnace has a special vacuum and protective gas equipment. A gas analysis system for N_2, H_2, CO, CH_4 and dew point instruments are integrated in the gas supply. This is necessary to avoid oxidation of the metals at high temperatures and to get bright surfaces. By this way, the metal samples can be heated from room temperature up to their melting points.

The accuracy of the measurements was determined as about +/- 3,5 %. Parallel to this, the influences of temperature between sample and black body and also between sample and surroundings on the uncertainty of the measured spectral emissivities were additional experimentally proofed.

3. SELECTED RESULTS OF EMISSIVITY MEASUREMENTS

The measurements took place in steps of 50-200 K in the range of 200 °C up to maximum 1200 °C on selected steel qualities and non-ferrous metals which are representative for heat processes (for example before lamination and forging) as well as for bright annealing in vacuum and protective atmosphere furnaces. Based on these investigations, a big number of spectral emissivities of metals is available.

In fig. 2 normal spectral emissivities for different non-ferrous metals (Al-alloys, Cu-alloys, pure nickel, brass, and bronze) were presented.

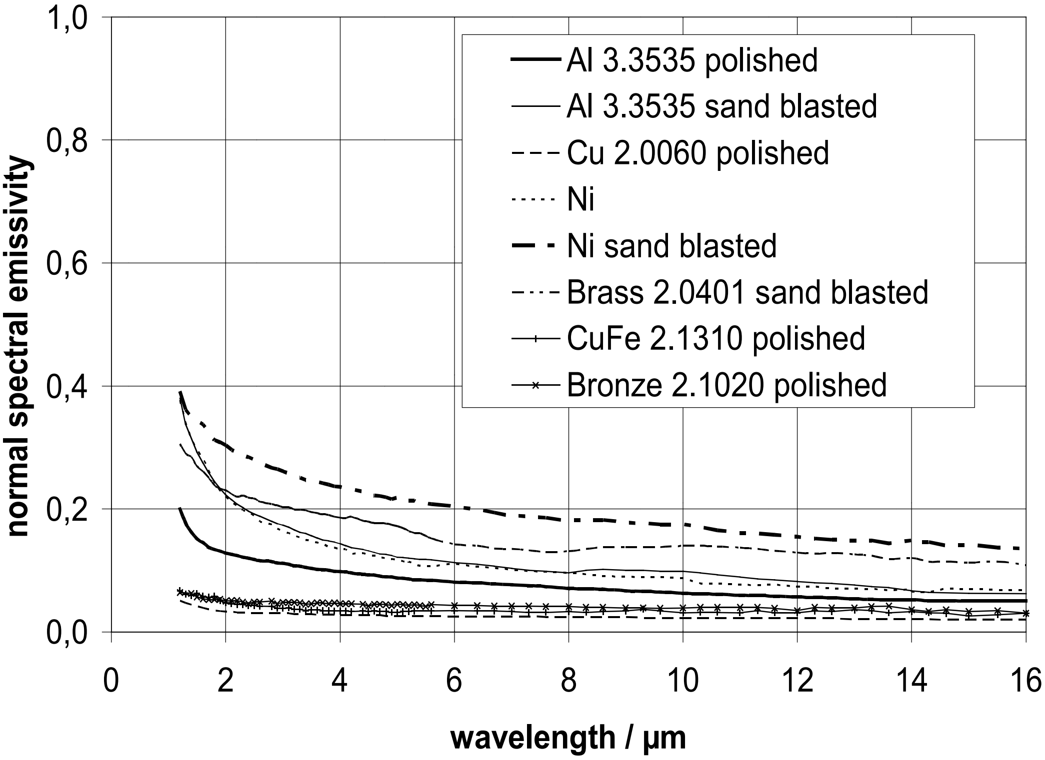

Fig. 2. Spectral emissivities of selected non-ferrous metals at 400 °C.

Fig. 3 shows normal spectral emissivities for different alloyed steel grades at 1000 °C. The values of the blank surfaces are in a relatively small band. Whereas oxide layers have a significant influence on the emissivities, which is obvious identifiable in fig. 3.

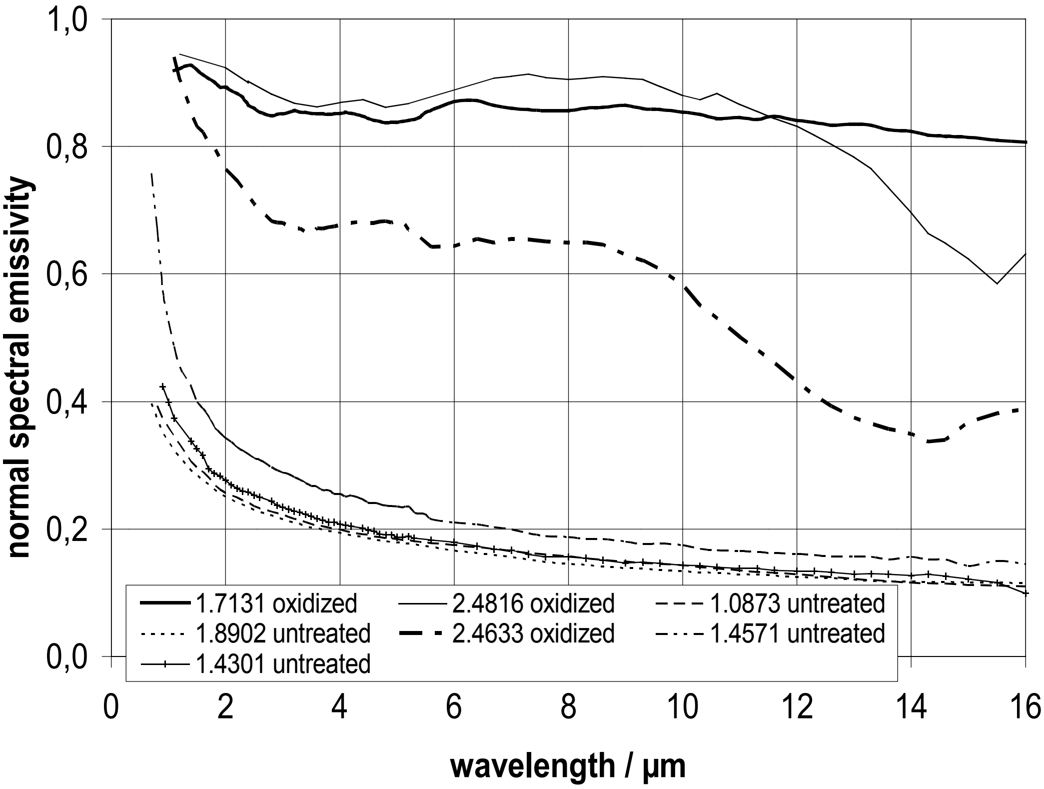

Fig. 3.: *Spectral emissivities of selected untreated and oxidized steel grades and high temperature alloys at 1000 °C (material no. according to DIN).*

Temperature dependent spectral emissivities of a bright sample of a low alloyed steel (steel grade no. according to DIN, 1.7131) are presented in fig. 4. The determined temperature dependency of the spectral emissivities of this sample is relative small. The emissivities of the second measurement at 200 °C (after cooling down from 1200 °C) show lower values as the first measurement at this temperature. This may be caused by changes of the sample surface during the heating during the emissivity measurements.

The following two fig. 5 and 6 show temperature dependent spectral emissivities of two different pretreated brass samples (2.0265). The sample in fig. 5 was polished (roughness 1.0 µm) and the sample in fig. 6 was sand blasted (roughness 2.3 µm)
The values of the emissivities of the polished samples are relatively low and the temperature dependency is relative small. The emissivity values of the sand blasted sample are higher and show a higher temperature dependency.

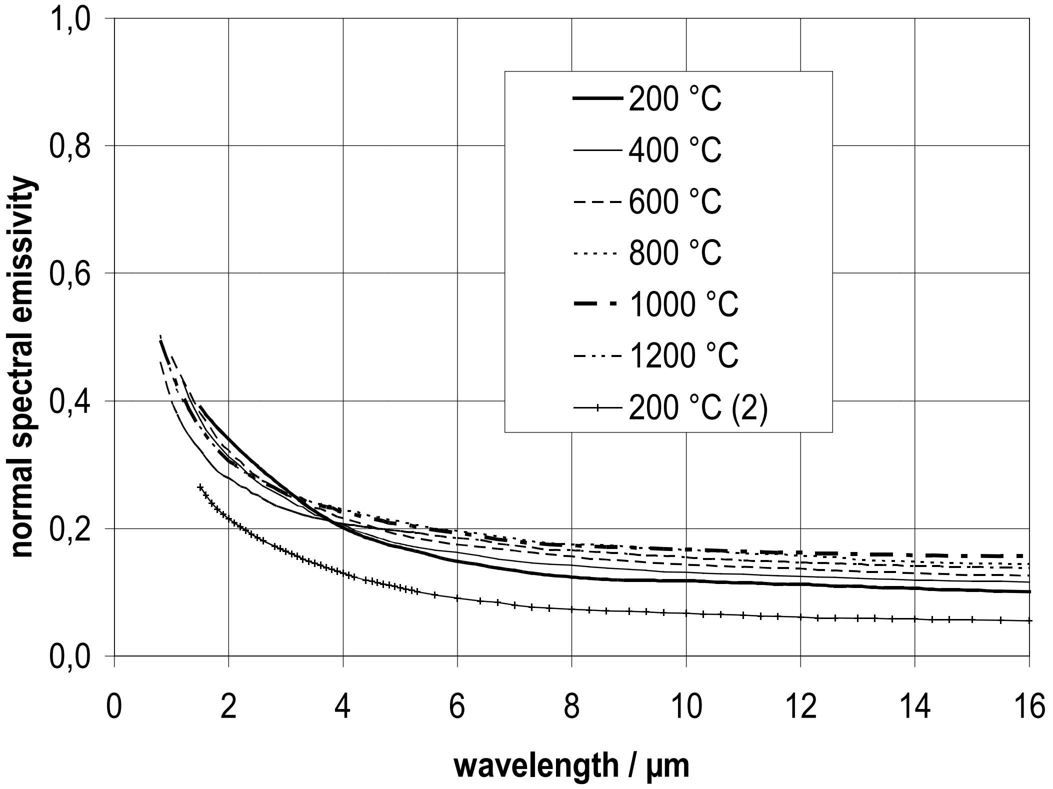

Fig. 4. Temperature dependent spectral emissivities of a bright sample of a low alloyed steel sample (1.7131).

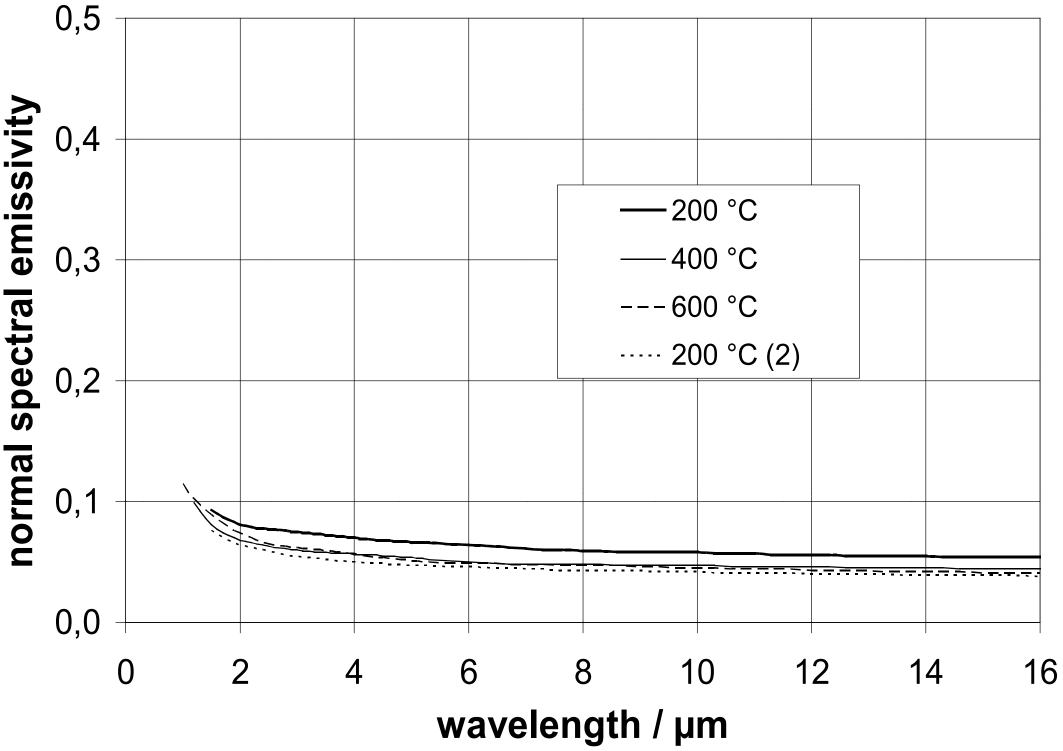

Fig. 5. Temperature dependent spectral emissivities of a polished brass sample (2.0265; roughness 1.0 µm).

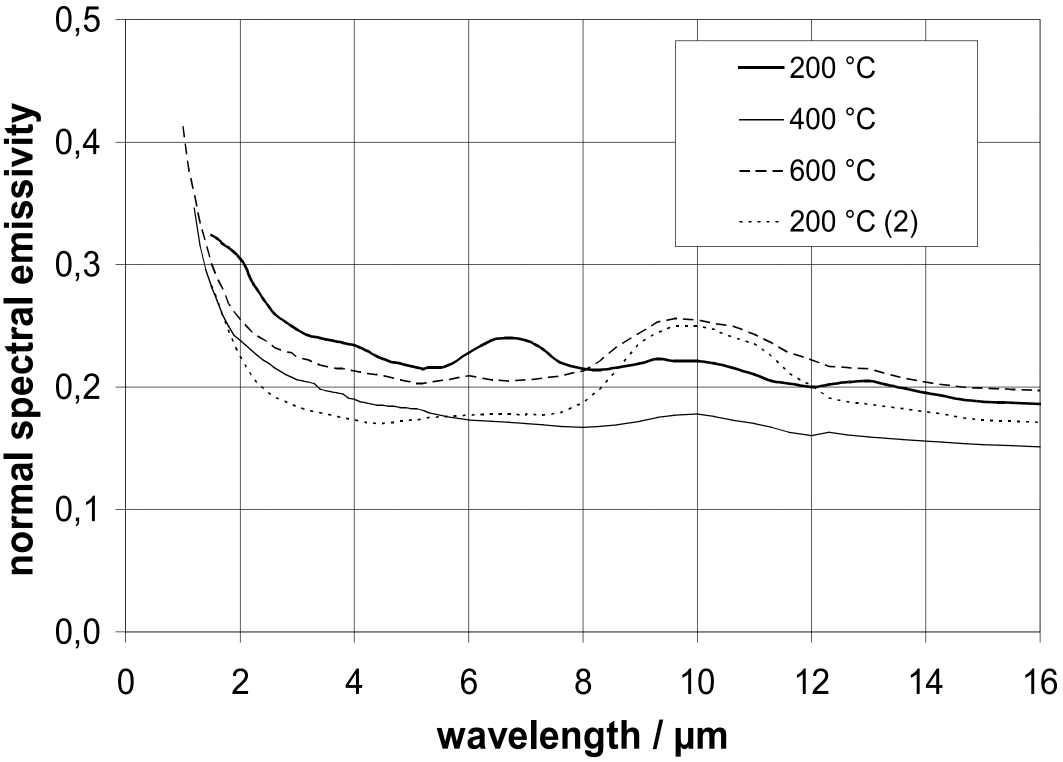

Fig. 6. Temperature dependent spectral emissivities of a sand blasted brass sample (2.0265; roughness 2.3 µm).

The heating of oxidized samples in nitrogen atmospheres shows two interesting material depending effects. Fig. 7. shows temperature dependent spectral emissivities of a pre-oxidized Inconel 600 sample. This sample shows at higher temperatures an week oxidation. The second effect is presented in Fig. 8. The fig. shows temperature dependent spectral emissivities of a pre-oxidized low alloyed steel sample (1.7131). At higher temperatures a strong reduction in nitrogen occurs and the spectral emissivities changed to a type of bright metals.

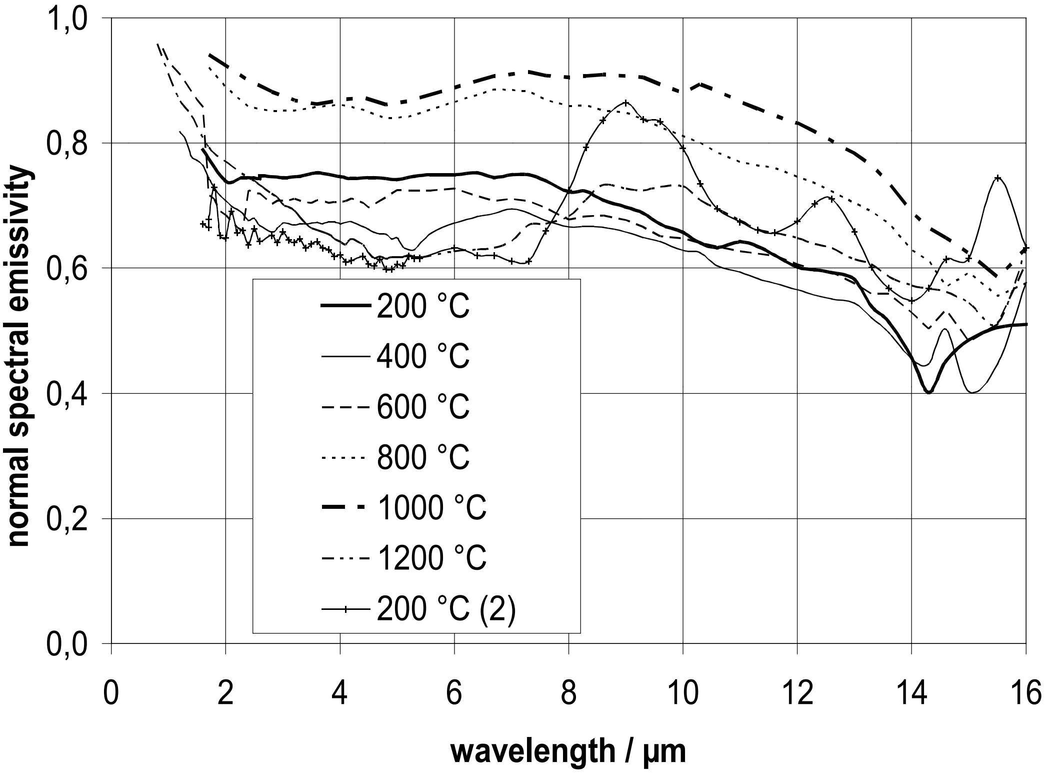

Fig. 7. Temperature dependent spectral emissivities of pre-oxidized Inconel 600 sample, measuring atmosphere Nitrogen.

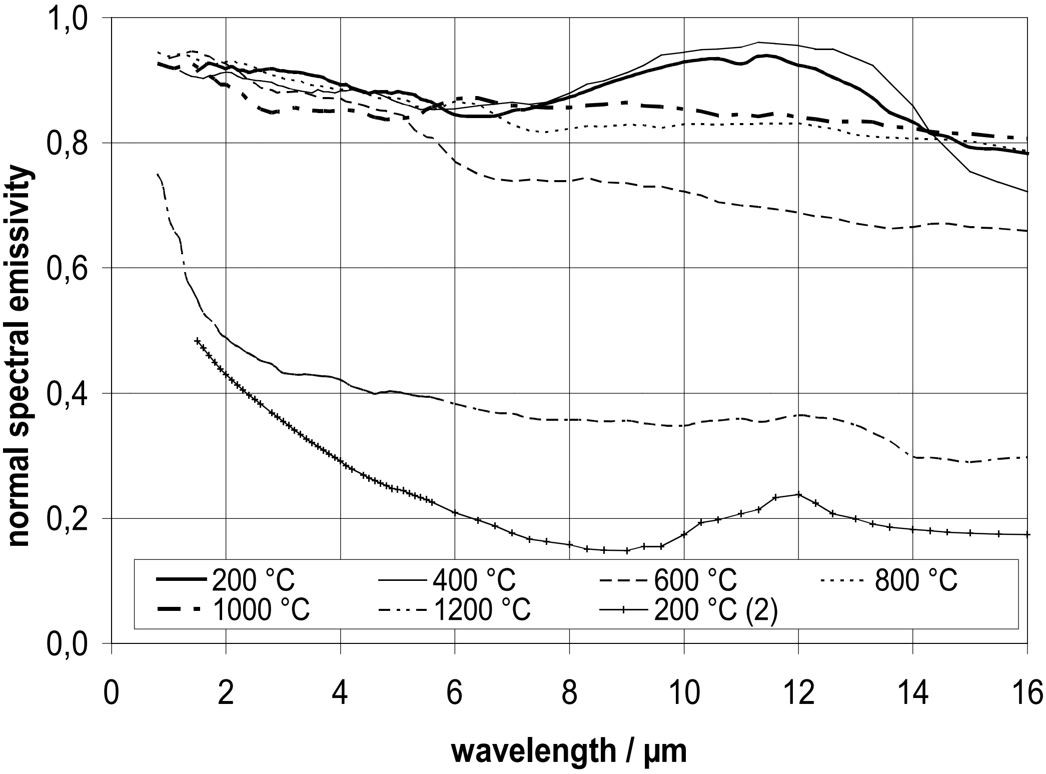

Fig. 8. Temperature dependent spectral emissivities of pre-oxidized low alloyed steel sample (1.7131), measuring atmosphere Nitrogen.

4. APPLICATION OF MEASURED SPECTRAL EMISSIVITIES

Temperature dependent spectral emissivities were chosen as measurand. They give good qualitative and quantitative information about the radiation properties of metals. Particularly surface effects, like roughness, oxide layers, and changes of these conditions were taken into consideration. Therefore, the spectral emissivities are very informative physical properties for the description of thermal radiative properties.
The measured spectral emissivities can be used for spectral models of radiation heat transfer [3].
These spectral emissivities are the basis for calculation of temperature dependent total emissivities [4, 5]. These values were required in the majority of heat transfer calculations based on grey radiative properties, for the construction, and design of thermal technical plants and for control of thermal processes.
Furthermore, the measured spectral emissivities can also be used as the basis for the calculation of temperature dependent band emissivities for pyrometrie in several wavelengt ranges, and for process controlling.
A particular advantage of the so calculated total and band emissivities, compared with temperature independent grey radiative properties, is, that the temperature dependence takes into consideration. Therefore, this leads to a higher accuracy of the models [5].

5. SUMMARY

The determined temperature dependencies of the spectral emissivities of bright metals are mostly relative small. As a further parameter, the roughness showed measurable effects. Oxide layers lead to strong and, sometimes temperature dependent changes of spectral emissivities.
The measurements were carried out for more than 50 metals [6, 7].

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